ANATOMY AND PHYSIOLOGY OF THE EYE, WITH HINTS FOR THE PRESERVATION OF THE EYE-SIGHT

BY

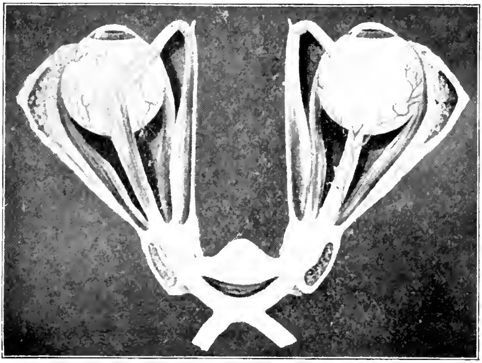
J. FREDERICK HERBERT, M.D.


Sincerely yours
J. Fredk. Herbert, M.D.

ANATOMY AND PHYSIOLOGY OF THE EYE

WITH HINTS FOR THE

PRESERVATION OF THE EYESIGHT



THE RELATIVE POSITIONS OF THE EYEBALLS, MUSCLES AND NERVES

BY

J. FREDERICK HERBERT, M. D.

THIRD EDITION

PUBLISHED AT 1516 LOCUST STREET
PHILADELPHIA, PA.

PREFACE.

The major portion of this monograph was delivered as a lecture to the young men of the Cheltenham Military Academy, at Ogontz, Pa. It was illustrated with especially prepared lantern slides. Some of the illustrations were borrowed from scientific treatises.

Most books on the eye are so technical that they are practically sealed to all but the specialist, who is compelled to have a knowledge of anatomy, physiology, and optics.

In this work it has been the author's endeavor to omit all strictly scientific and medical conclusions.

In an effort to popularize facts and accepted theories, he has made use of his own library on the subject, as well as gathered all available material. In consequence, he does not claim entire originality in the work.

He trusts that his attempt to render this branch of science intelligible to the general reader will meet with success.

This done he will feel repaid for all the labor involved in the preparation of a work of this kind.

TABLE OF CONTENTS.

ILLUSTRATIONS.

INTRODUCTION.

The object of this lecture, as indicated by the title, is to place such facts in your possession that will better enable you to assist nature in the care of your eyes, and to pay proper attention to the causes that may tend to the arrest and prevention of impairment and loss of vision.

We all appreciate that vision is the most valuable of the special senses; it is the choicest gift of nature. By it we derive more knowledge of the world about us than through any other medium, and yet there is not an organ which is more abused than the eye. Without doubt the most unfortunate affliction that can befall any one is the loss of his eye-sight. Although it is of such great importance to us all, yet there are comparatively few persons who have any definite ideas concerning the eye, either as to its structure or as to the manner in which it aids in the production of sight.

The common opinion that the human eye is theoretically perfect is erroneous; indeed, it is so imperfect that it led Helmholtz to remark: "It is not too much to say that if an optician wanted to sell me an instrument which had all the defects of a human eye, I should feel myself quite justified in blaming his carelessness in the strongest terms, and giving him back his instrument."

However, the various adjustments by which the defects are neutralized and compensated, overcome the faulty conditions to a great degree, and enable the organ to fulfill all the ordinary requirements which may be made upon it.

In fact, the author is happy to state that many of the defects that nature has unprovided for, have been remedied by art.

Before beginning any life-work requiring the use of the eyes, we should know and have the assurance of one who is competent to judge that the organs of sight are in proper working condition. Before sending a child to school its parents and guardians should have his eyes thoroughly examined in order to ascertain whether they are capable of performing the amount of work that may be required of them. Many are the instances where a child has been thought stupid, when in reality the entire fault has been "defective vision," which when properly corrected, wrought an entire change in the demeanor of the child.

The eye is so delicately adjusted that if heed were paid its warnings very little harm would result, but, unfortunately, everyone seems to think that at all times and under all physical conditions this little organ can be kept at high pressure; they never stop to think that injury or disease may lead to blindness which can be directly attributed to carelessness and neglect.

In the following pages a concise description of the eye itself, with an explanation of its mode of action in health, together with a brief outline of the abnormal conditions which physicians are called upon to treat, may be found.

THE HUMAN EYE.

Part I.

For sake of elucidation and comparison, the eye may be likened to a photographic camera ; in fact, the eye and the camera resemble one another in many respects, and to a casual observer they seem to be identical in construction, but as a practical instrument, the superiority of the former

THE HUMAN EYE.

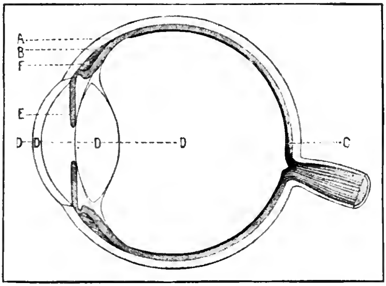


Figure 1.

A. Sclerotic Coat. B. Chorioid Coat. C. Retina.
D. Refractive Media. (Lens System.) E. Iris. (Diaphragm.)
F. Ciliary Muscle.

over the latter is quite evident. The former (figure 1) is a masterpiece of nature, and its mechanism cannot be imitated by man ; the latter (figure 2) is but the handiwork of human art.

In the examination and study of the organ of vision some systematic plan should be followed. Before describing the eyeball it is well to become acquainted with the

exterior portion of those parts surrounding the globe—*i. e.*, the appendages of the eye, before considering the eye proper, from without inward.

The appendages of the eye include :

I. The Eyebrows.	V. The Conjunctiva.
II. The Eyelids.	V. The Lacrymal Apparatus.
III. The Eyelashes.	VII. The Meibomian Glands.
IV. The Orbit.	VIII. The Extrinsic Muscles.

I. Eyebrows or Supercilia (figure 3) are two arched prominences composed of short, thick hairs that are di-

THE PHOTOGRAPHIC CAMERA.

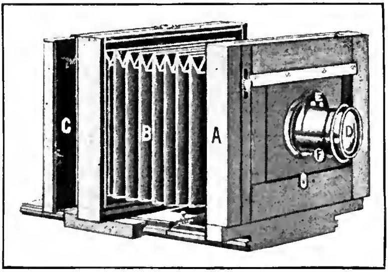


Figure 2.

A. Outside wood case. B. Inside or bellows (black).
C. Sensitive film or plate. D. Lens. E. Diaphragm.
F. Rack and Pinion. (Compare with similar letters in figure 1.)

rected obliquely up and out from the median line. Their function is to protect the organ from injury and to prevent any perspiration that may trickle down the forehead or other foreign material from entering the eyes. They are also useful to shade the eyes from excessive light. In addition, they have æsthetic functions, being powerful organs of expression ; for example, a frown is produced by wrinkling or depressing the brows, whilst by elevating them surprise or contempt is expressed almost as plainly

as by words. Heavy eyebrows and long eyelashes are considered beautiful, and are very much admired.

II. Eyelids or Palpebra (figures 3, 4 and 5). Two thin folds placed in front of the eye. The protective covering of the eyeball consists of skin, muscles and glands. The upper lid is the larger, and is the more movable of the two. Besides shielding the eye from injury, the lids, by their constant motion, moisten and lubricate their inner surfaces and the anterior portion of the eyeball, thus enabling them to glide easily and without friction, the

FRONT VIEW OF EYE.

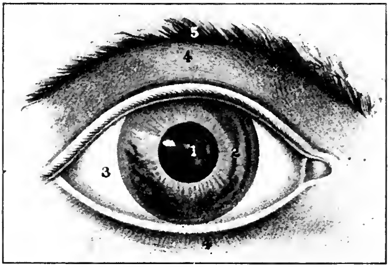


Figure 3.

1. Pupil. 2. Iris. 3. Sclerotic. 4. Palpebra or eyelids. 5. Supercilia or Eyebrows.

polish and transparency of the cornea being thus maintained. Figure 4 shows a vertical section of the upper eyelid

III. Eyelashes or Cilia (figure 4) act as sentinels, guarding the organ against injury from foreign particles. They project in two or three rows from the outer edge of the margin of each lid. Those of the upper lid are the more abundant, the thicker and longer, and are curved downward and outward. In the lower lid the cilia are less numerous,

smaller, and are curved upward and outward. They undergo a constant renewal, each lash reaching maturity in five or six weeks' time. It then drops out, and is succeeded by a new one. Frequently a young hair may be seen projecting by the side of an old one, ready to take upon itself the duty for which it has been called into existence.

VERTICAL SECTION OF EYELID.

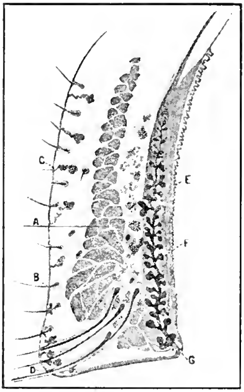


Figure 4.

A. Orbicularis muscle. B. Small hair in skin of lid. C. Sweat gland.
D. Eyelashes—in the lower row can be seen where a young lash is just behind and ready to take the place of an old one.
E. Conjunctiva—lining of the inner surface. F. Meibomian gland.
G. Excretory duct at the border of the lid.

IV. The Orbit (figure 7) is the cavity under the forehead, formed by the bones of the skull. It is conical in shape with its base directed forwards and outwards. Its bony walls are quite thin, but its edges are comparatively strong, particularly the upper one, which is more prominent and overhangs the eye, thus well adapting it for shielding the organ from injury. Between the orbital walls

and the eyeball there is a padding of fat, which fills the interstices between the muscles, nerves and blood vessels, thus protecting the parts from harm ; also facilitates the movements of the eyeball, thus insuring a most extensive and free range of vision.

V. The Conjunctiva, or connecting membrane (figures 4 and 5), is a delicate, highly sensitive mucous membrane, connecting the eyelids with the eyeball, being continuous with the skin at the margin of the lids. It covers the

POSTERIOR PORTION OF EYELIDS.
(RIGHT EYE.)

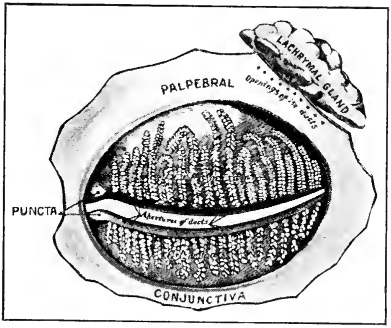


Figure 5.

Showing relative position of Lacrymal Gland. The Meibomian Glands present the appearance of parallel strings of pearls.

inner surfaces of the lids and is then reflected over the anterior portion of the globe of the eye.

VI. Lacrymal apparatus (figures 5 and 6) consists of:

a. The lacrymal glands.
b. The lacrymal ducts.
c. The lacrymal puncta.
d. The lacrymal canals.
e. The lacrymal sac.
f. The nasal duct.

a. The lacrymal glands are the glands that secrete the tears. Their composite size is about that of an almond.

b. The lacrymal ducts. These number from seven to ten; they are used to carry tears to the conjunctival surfaces.

c. The lacrymal puncta. These consist of minute orifices that can be seen on the margin of the lids. They serve as the beginnings of the lacrymal canals.

d. The lacrymal canals. These are two in number, the

LACRYMAL APPARATUS.

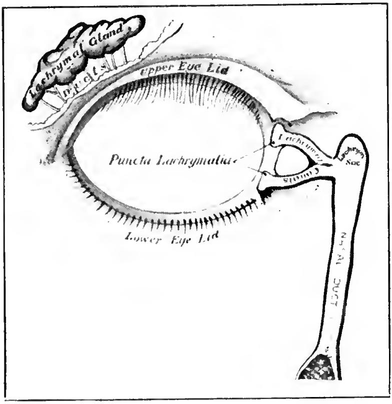


Figure 6.

Lacrymal Gland situated at the upper and outer portion.
Nasal duct situated at the inner and lower part of eye.

upper and the lower. They are intended to carry off the tears after having served the purpose of washing away any substance that may have been lodged on the conjunctival surface. When there is an excess of tears, as during weeping, the canals cannot carry the tears away quickly enough, consequently the tears run over and trickle down the cheek.

e. The lacrymal sac. This is an enlargement of the upper portion of the nasal duct.

f. The nasal duct. This consists of a membraneous canal that is situated in the nose. It begins at the lower portion of the lacrymal sac and terminates by a somewhat expanded orifice that is shaped like a trumpet end.

VII. The Meibomian Glands (figures 4 and 5). These

EYEBALL IN POSITION IN ORBITAL CAVITY.

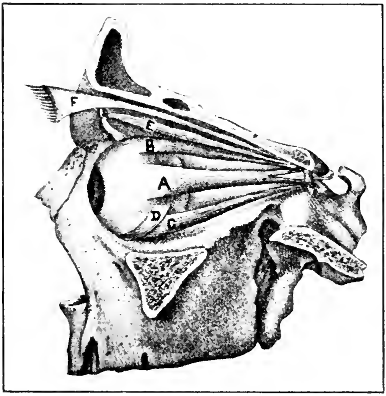


Figure 7.

Extrinsic Muscles of the Eye.

A. External Rectus Muscle. B. Superior Rectus Muscle.
C. Inferior Rectus Muscle. D. Inferior Oblique Muscle.
E. Superior Oblique Muscle. F. Levator of upper lid.

are the sebaceous glands of the eyelid. They are situated upon the inner surface. On everting the eyelid they can be distinctly seen through the mucous membrane presenting the appearance of parallel strings of pearls, or appearing like currants on a stem, each having an excretory duct at the free border of the eyelid between the rows of cilia. Their secretion acts as a lubricant, preventing adhesion of

the lids and not allowing the tears from coming in contact with the skin and thus running down the cheeks.

VIII. Muscles of the Eye (figure 7). The extrinsic muscles are attached to the globe, and each eye is provided with its own set of muscles. The muscles act in unison. By this arrangement the eyes are capable of being directed simultaneously to any object which it may be desired to view.

There are six muscles, and their action is as follows:

External Rectus Muscle, moving the eye outwards.

Internal Rectus Muscle, moving the eye inwards.

Superior Rectus Muscle, moving the eye upwards and inwards.

Inferior Rectus Muscle, moving the eye downwards and inwards.

Superior Oblique Muscle, moving the eye downwards and outwards.

Inferior Oblique Muscle, moving the eye upwards and outwards.

THE HUMAN EYE.

Part II.

The form of the human eyeball (figure 8) is that of a spheroid about one inch in diameter, having the segment of a smaller sphere engrafted on its anterior surface. The anterior face of this smaller sphere projects forward, as can readily be seen in looking at any eye from the side.

The smaller sphere is formed by the transparent cornea, the larger one consists of the sclerotic coat.

THE HUMAN EYE

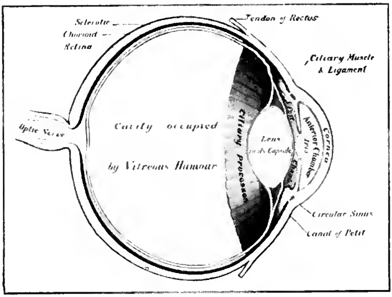


Figure 8.

Vertical section, showing the relative arrangement and positions of the various parts of the human eye.

The eye has three coats or tunics :

I. Sclerotic. II. Chorioid. III. Retina.

The refractive media or transparent portions of the eye are :

A. Cornea.
B. Aqueous Humor.
C. Crystalline Lens.
D. Vitreous Humor.

I. The Sclerotic Coat (figures 1, 3 and 8) is the thickest tunic of the eyeball, and forms "the white of the eye." It is a tough and elastic opaque membrane, constituting five-sixths of the diameter of the globe, the other sixth being formed by the cornea. It is well calculated to give shape to the organ and offer protection to the more delicate parts contained within. It also serves as an attachment for the muscles that move the eyeball.

II. The Chorioid Coat (figures 1 and 8) is the second or middle tunic of the eyeball. It lies between the sclerotic coat and the retina. It is quite thin, forming the vascular coat of the organ, and contains many minute tortuous bloodvessels. It serves as a nutritive organ for the other coats. On its inner surface it is covered with a dense layer of black pigment which absorbs all excess of light that falls upon it, thus preventing internal reflection which otherwise by reflection and diffusion would prevent accurate vision. This coat has been likened to the blackened inner surface of a photographic camera. It is sometimes absent, and when this is the case, as in albinos, there is considerable suffering from the dazzling effect of the light, vision always being below the normal.

III. The Retina (figures 1, 8, 9 and 10) is the terminal expansion of the optic nerve within the globe. It is an exceedingly complex and intricate structure, and when examined microscopically is found to consist of several layers. It is the nervous portion of the visual organ. It is the part on which the pictures of external objects are received and thence transmitted through the optic nerve to the brain. In health it is a very delicate, transparent membrane. Not all portions of the retina are equally sensitive. The macula lutea or yellow spot is the seat of the greatest acuity of vision, and here are formed the sharpest and most distinct images. In order to obtain the best

sight, our eyes are instinctively directed in such a way so that the rays coming from an object fall exactly on this portion of the organ. The rods and cones of the retina are generally considered to be the perceptive layer.

A. Cornea (figure 8) is a transparent, highly polished membrane forming the anterior portion of the eyeball. It occupies about one-sixth of the diameter of the globe. It

RETINA.

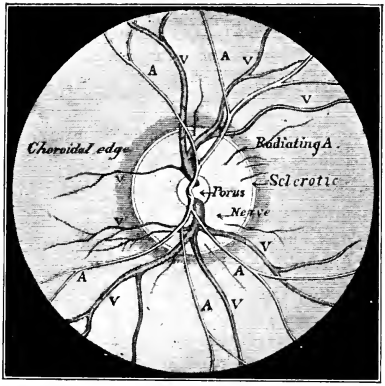


Figure 9.

Eye ground as seen by an examination with the ophthalmoscope. The circular plate in the centre of the illustration is the optic disc. The light branches "A" emanating from the centre are the arteries of the retina. The dark branches "V" going to and dipping down into the centre are the retinal veins.

fits into the sclerotic coat very much as a watch crystal is inserted into the rim of a watch case. Although it appears structureless, yet under the microscope it is found to consist of five layers composed of cells and granules. It is through this membrane that the color of the eye (the iris) is seen. Were it not for the eyelids and the eyelashes the cornea would be very prone to injury.

B. The Aqueous Humor (figure 8) is a clear, watery fluid which occupies the space called the "Anterior and the Posterior Chamber," which is situated between the cornea and the crystalline lens, the iris separating the two parts.

C. The Crystalline Lens (figure 8) is a perfectly transparent, highly polished, refractive body, shaped very much like a double convex lens, with the curve of its posterior surface somewhat greater than that of its anterior. It is supported between the iris and the vitreous humor by a thin, transparent, elastic capsule. The lens is capable of having the convexity of its surfaces increased by the ciliary muscle, which change is of the utmost importance, since it enables us to "accommodate"—that is, to see

SECTION THROUGH THE RETINA.

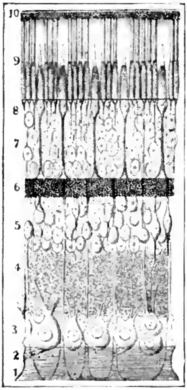


Figure 10.

In all there are ten (10) layers, composed of:

1. Internal limiting membrane. 2. Fibrous layer. 3. Layer of vesicles. 4. Molecular layer. 5. Inner nuclear layer. 6. Outer molecular layer. 7. Outer nuclear layer. 8. External limiting membrane. 9. Layer of rod and cones. 10. Pigmentary layer.

near objects equally well as distant ones. Normally, the crystalline lens is as clear as the purest crystal, hence its name. In the later years of life the lens becomes more or less cloudy, giving rise to the condition known as Cataract.

D. The Vitreous Humor (figure 8) is a transparent, colorless, gelatinous mass, resembling molten glass. It occupies about four-fifths of the cavity of the globe. It contains a depression or hollow in front for the reception of the crystalline lens. Its principal functions are to aid in bringing rays of light to an accurate focus on the retina, to contribute to the solidity of the eye, and to hold the retina in proper place.

The Iris (figures 3 and 8) is a thin, muscular curtain which is suspended in front of the crystalline lens. It serves the purpose of a diaphragm, thus cutting off all superfluous light and correcting the spherical aberration which is present in every crystalline lens. It is composed of radiating and circular muscular fibres. The former converge from the circumference towards the pupil, which they serve to dilate. The latter encircle the pupillary opening, and in response to their action the pupil becomes contracted. It is the membrane that gives the eye its special color, and upon which the beauty of the organ, to a great degree, depends. It is perforated in the centre, making a circular opening known as the pupil. During distant vision the pupil becomes expanded and during near vision it is contracted.

The Pupil (figure 3) forms the "black of the eye." It is a hole in the iris. The quantity and quality of the light that falls upon the eye regulates in measure the size of the pupil. The greater the amount of light the smaller the pupil. As the iris expands the pupil becomes contracted. This can be verified by asking some one to face

the bright light coming through a window and noticing the diminished size of the pupil, and then having the same person turn their back to the window and notice how quickly the pupil enlarges. It is for the same reason that in entering from a dark to a light room one feels dazed until the pupil can adjust itself to the conditions of its new surroundings.

The Ciliary Muscle (figure 8) consists of a great number of delicate bands of muscular tissue, which form a circle around the edge of the crystalline lens. Lying just behind the iris, although small and insignificant in appearance, the muscle is an essential part of the eye, as, by its action, contracting—now more, then less—the convexity of the crystalline lens is increased or diminished, according to the necessity of the moment; thereby focusing all external objects accurately on the retina.

NERVES OF THE EYE.

1. The Optic Nerve (figures 8 and 11) is a nerve of special sense; "the sense of sight" which, on entering the globe, expands and becomes the retina.

2. Motor Nerves, that help control the various movements of the eyeball.

BASE OF THE HUMAN BRAIN.

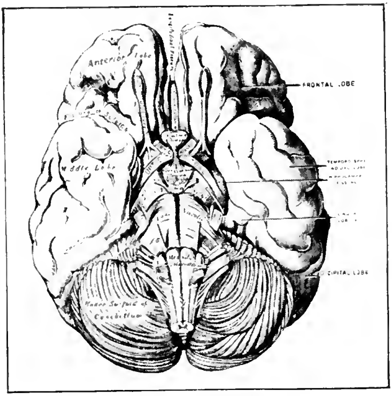


Figure 11.

The optic tracts and the optic chiasm where optic nerves cross just before entering the eye.

3. Sensory Nerves, which are used for taking cognizance of impressions received from the external source by means of contact.

ARTERIES OF THE EYE.

The arteries of the eye supply it with nourishment. A portion of them pass through the optic nerve similar to

the plumbago in a lead pencil, and when they reach the inner portion of the organ divide into four branches, one going to each quarter.

VEINS OF THE EYE.

There are four principal veins in the eye. These are used to carry off the blood after it has served its purpose.

PHYSIOLOGY OF VISION.

A number of conditions are essential to normal vision, *i. e.*, The object which is desired to be seen must be illuminated so that the rays of light emanating from the same will reach the eye.

The axis of the eye must be directed towards the object which is desired to be seen.

The eye must be capable of receiving the rays which must pass unobstructed from the object through the media to the retina.

The connection which exists between the retina and the brain must be in a normal condition.

The visual centre, or that portion of the brain which is allotted the sense of seeing, must be capable of elaborating the impressions conveyed to it into what is termed vision.

The dioptric apparatus is composed of a number of lenses possessing a high condensing power; this, which is composed of the cornea, the crystalline lens, the aqueous and vitreous humors, assist in bringing the rays coming from an object to a focus on the macula lutea or yellow spot in the retina, this being the portion of the retina which receives a correct impression of objects.

VISUAL ANGLE.

The size of the retinal image depends upon the size of the visual angle, one being in direct proportion to the other, the nearer the object is brought to the eye the greater being the visual angle and the larger is the image.

In order that the retinal image may be of the necessary size to excite perception, the object producing it must form a certain visual angle, which must not be too small.

A good illustration and test of the angle of vision can be made by placing a coin near the eye and looking towards some distant object. If the coin be held close enough to the eye it will obscure the far object from view,

VISUAL ACUTENESS.

Figure 12.

The letters at 8 and 12 feet are as plainly seen by the eye as the one at 4 feet; the lines subtend from all of the letters at the same angle.

but if the coin be removed to arm's length distance it will appear much smaller, allowing the distant object to be seen.

VISUAL ACUTENESS.

In ophthalmic practice the acuity of vision is determined by a series of appropriate letters of various sizes (figure 12), each having a definite standard value to be distinguished at a specified distance by the normal eye. Each component stroke of the letter is seen under an angle of one minute, the entire letter being enclosed within an angle of five minutes.

As the lines in the illustration, diverging from the eye, subtend at an angle of five minutes, any object placed in this angle can be readily distinguished by an eye which has normal acuity of vision.

The letter E at twelve feet is three times higher than the one of four feet. Should the object be brought nearer, the visual angle would be greater, and consequently a larger retinal image would be the result—if, for instance, an object the size of the letter E at twelve feet were brought, say to four feet or nearer, the image on the retina would be increased and the object would be seen more dis-

ACCOMMODATION.

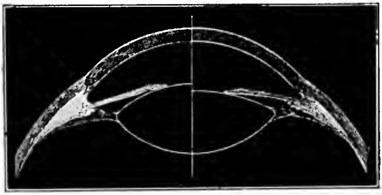


Figure 13.

Right half is represented as adjusted for distant vision, and left half for near vision.

tinctly. If, however, the letter or object which, under the rule can only be seen well at four feet, were removed to twelve feet, it would become too indistinct to recognize, as the retinal image would be too small.

ACCOMMODATION.

The term as used in this connection is the power the eye has of adjusting itself and rendering near points visually distinct. It is a semi-voluntary action. The act is dependent upon the physiological power of the ciliary muscle

and the inherent elasticity of the crystalline lens. This lenticular mobility is greatest in youth, gradually diminishing as age advances.

Rays coming from a near object are more or less divergent, and should they enter a normal eye when it is in a state of rest (that is, adjusted for distant objects), they would be focussed at a point behind the retina.

What then must take place in order to bring the rays from the object to a focus on the retina? The refractive power of the eye must be increased, this being accomplished by a change in the crystalline lens, which has been

ACCOMMODATION.

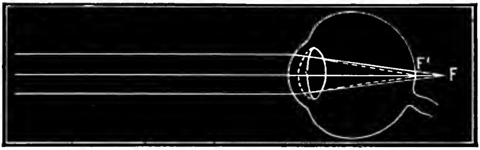


Figure 14.

By an increase in the convexity of the crystalline lens, the point F, at which the solid lines meet behind the retina, are brought to a focus at point F′, as shown by dotted line.

shown to take place in the anterior surface of the lens, which becomes more convex and approaches the cornea, the posterior surface of the lens also becoming a trifle more convex.

This change is affected by the ciliary muscle. To show that this does take place, can be proven by holding a piece of netting or gauze twelve or fifteen inches in front of your eyes, and fixing your gaze intently on some distant object. As long as the distant object is clearly seen, the meshes of the netting will be indistinct, while if the meshes be accu-

rately seen the distant object will be obscure and no longer plainly visible; in other words, there has been a change in the convexity of the lens, this being the greater for near and the less for distant objects.

The alteration in the curvature of the crystalline lens is shown in figure 13, which represents a horizontal section of the anterior part of an eye. The right half of the figure shows the eye when at rest—that is, adjusted for distant objects. The left half represents it as accommodated for near vision, showing an increase in the convexity of the crystalline lens. Figure 14 illustrates how an increase in the thickness of the lens shortens the focus of rays, which would otherwise come together behind the retina and not produce a proper focus.

THE EMMETROPIC OR NORMAL EYE.

When an eye is in a state of rest—that is, when the ciliary muscle is relaxed to its fullest extent and the accommodation suspended—the rays emanating from a distant object striking the convex surface of the cornea in parallel lines and in conjunction with the crystalline lens, and the aqueous and vitreous humors being brought to a focus on

THE EMMETROPIC OR NORMAL EYE.

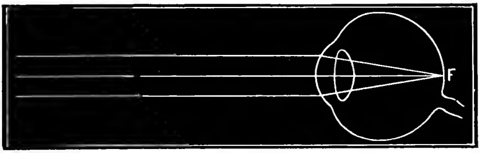


Figure 15.

Parallel rays focus directly on the retina at F.

the retina, thus producing a perfect and distinct image without any artificial aid, we have a "Normal Eye."

The emmetropic eye is usually about one inch long in its anteroposterior diameter, yet it may be either longer or shorter and still be normal, providing that if it be the former the refraction of the media be correspondingly increased, and if it be the latter correspondingly lessened.

HYPERMETROPIC OR FAR-SIGHTED EYE.

Hypermetropia caused by an anteroposterior shortening of the globe, may be congenital or acquired. It is due to a faulty shape of the eyeball or to a too little strength of the refractive media. In each case the visual angle is too long and the rays come to a focus behind the retina.

The sight is generally good for distant objects, but near

HYPERMETROPIC OR FAR-SIGHTED EYE.

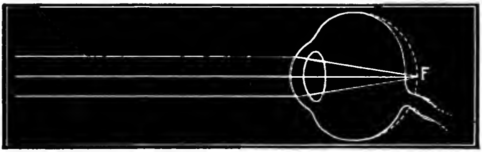


Figure 16.

Parallel rays coming to a focus behind the retina at F.
Dotted line shows shape of normal eye.

objects become blurred and cannot be distinctly seen without undue accommodative effort. The eyes cannot be used for any period of time without becoming much fatigued. The muscular effort to adjust the rays on the retina is too great and the ciliary muscle soon relaxes, causing the object looked at to run together, leading to headache, asthenopia, and sometimes strabismus. Hypermetropes generally complain of headache, especially over the eyes, and quite often attribute the pain over and in the eyes to

nervous headache ; a condition that would be soon relieved by proper convex glasses. A convex lens is necessary to bring the rays to a proper focus on the retina. (See figure 17.)

HYPERMETROPIC OR FAR-SIGHTED EYE.

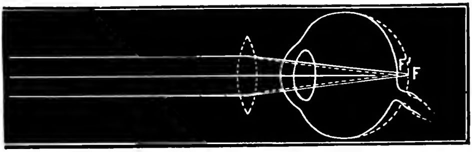


Figure 17.

A proper convex lens placed in front of this eye will shorten the rays from F to F′ so that they will focus exactly on the retina.

The visual angle in hypermetropic eyes may be so long that glasses are required for distance to obtain clear and distinct vision as well as for near work. In young hypermetropes the ciliary muscle often has sufficient power to overcome effects of a moderate amount of hypermetropia.

MYOPIC OR NEAR-SIGHTED EYE.

In myopia parallel visual rays are brought to a focus anterior to the retina (see dotted lines in figure 18). The condition is either hereditary or acquired. In the former it is generally due to a lengthening of the anteroposterior optic axis or a state of too great a convergence of the media, while in the latter it is dependent upon prolonged strain during near vision. The condition is either progressive or stationary. In the latter it is generally of low

MYOPIC OR NEAR-SIGHTED EYE.

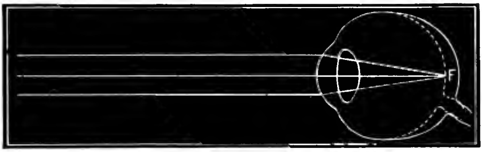


Figure 18.

Parallel rays coming to a focus at F before they reach the retina.
Dotted line shows shape of normal eye.

degree, whereas in the former it is of higher grades, which always have a tendency to increase. In myopes the power of observation for distant objects is limited, and the more they accommodate and try to see, the more blurred becomes the image of the distant object.

Treatment is merely orthopedic and preventive. The condition cannot be altered. Hygienic methods with the correction of the refractive error so as to cause the myopia

to remain stationary, are necessary. Stooping or reading in a recumbent posture must be avoided. Such eyes should not be used at dusk or by bad light.

MYOPIC OR NEAR-SIGHTED EYE.

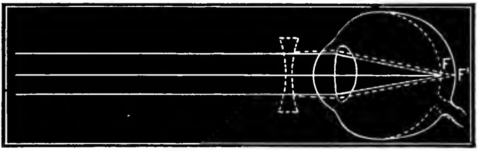


Figure 19.

A proper concave lens placed in front of this eye will lengthen the rays from F to F' so that they will focus exactly on the retina.

The weakest concave glasses which enable such eyes to unite divergent rays directly upon the retina, should be worn. Myopes who continue to strain their eyes will only increase their trouble, whereas should they wear suitable glasses they will check the disease. In such cases a concave lens is necessary to bring rays to a proper focus on the retina. (See figure 19.)

ASTIGMATISM.

Astigmatism is a condition of an eye whose curvature is unequal, the radius being greater in one direction than

TEST CARD FOR ASTIGMATISM.

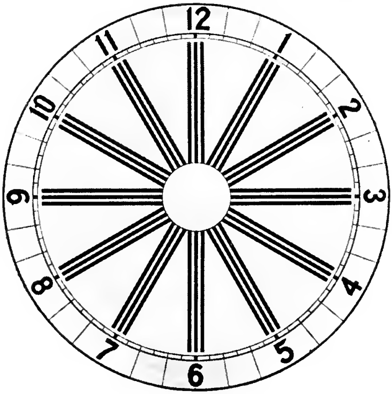


Figure 20.

Chart used for the detection of astigmatism. To a normal eye all the lines should appear equally distinct.

in the other. The shape of the eye may be likened to that of the bowl of a spoon. This want of symmetry in the dioptric apparatus is nearly always situated in the cornea, but similar inequalities may also exist in the crystalline lens. Although this defect is very common, yet not until the last few years has its frequency and importance been fully recognized. Nearly all eyes are more or less astigmatic, the cause usually being congenital, but the con-

dition may be acquired. On account of the asymmetry of the refracting surfaces, it produces a distorted image on the retina, which disturbs and diminishes the acuity of vision according to the degree of the defect. Both distant and near vision are equally affected, since at no point can a distinct image be obtained. Vision is not only blurred as in hypermetropia and myopia, but it presents certain peculiarities—a sphere, for instance, appearing elliptical in shape.

TEST CARD FOR ASTIGMATISM.

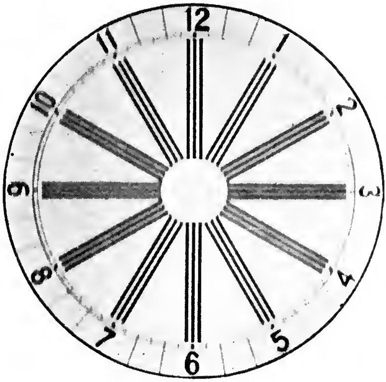


Figure 21.

Chart illustrating appearance of disc in astigmatism.

Another distinguishing feature of this defect is the fact that certain groups in a series of lines, such as represented in figure 20, are seen with more distinctness and appear blacker than those that are situated in the opposite meridian. For this reason a common complaint of those who are affected with the condition is the trouble they have in recognizing the hands of a clock at certain hours.

To an astigmatic eye a chart similar to that shown in

figure 20 appears partly blurred as the one shown in figure 21. For example, a star forms an image upon the retina, which, instead of being seen as a point, will appear as a line or an oval. The meridia of the greatest and the least refraction are called principal meridians. In speaking of the principal meridians of astigmatism, the vertical and horizontal are usually meant. They may, however, occur in any position, and they are, as a rule, with but few exceptions, found to be at right angles to one another.

Myopes usually see the vertical set of lines the most distinctly and hypermetropes the horizontal ones. If this

CYLINDRICAL LENSES.

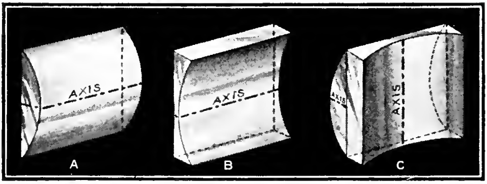


Figure 22.

A. Convex cylindrical lens used for the correction of hypermetropic astigmatism.
B. Concave cylindrical lens used for the correction of myopic astigmatism.
C. Concavo-convex cylindrical lens used for the correction of mixed astigmatism.

be reversed, astigmatism is said to be against the rule. It is not uncommon to find the eye faulty in the oblique meridians. Astigmatism cannot be cured, but it can be corrected. In the treatment of this defect, the rays of light must be gathered into a single focus. For this purpose recourse must be had to properly selected cylindrical lenses, such as those that are represented in figure 22.

Ordinary spherical lenses will not answer for the correction of astigmatism, since the rays passing through such lenses are refracted equally in all directions, and what is

desired is to find a lens that will refract or collect rays in but one direction. In the correction of astigmatism, not only must the proper neutralizing lens be found, but the angle of the astigmatism be determined. Correcting lenses are prescribed and ground in accordance with the formula adapted to each individual case.

The selection of these lenses can only be determined after careful and repeated examinations. This important work should only be entrusted to a competent physician. No matter how slight the astigmatism, it should be corrected, as it is the prime factor of more headaches, nervous and functional disorders, than all other ocular errors combined. Such conditions, if permitted to go unheeded, incapacitate the person for mental labor, and often distract the sufferer to such a degree that life does not seem worth living. In fact, the author has had cases on the verge of insanity, and those even afflicted with epilepsy, in which the apparent underlying cause was astigmatism, and which were cured by careful treatment and properly selected lenses.

VARIETIES OF ASTIGMATISM.

1. Simple Hypermetropic Astigmatism.
2. Simple Myopic Astigmatism.
3. Compound Hypermetropic Astigmatism.
4. Compound Myopic Astigmatism.
5. Mixed Astigmatism.
6. Irregular Astigmatism.

1. In simple hypermetropic astigmatism, the rays coming through one of the principal meridians, which in this case is normal, focus exactly on the retina, while those coming through the meridian at right angles to the former focus beyond the retina. See figure 23.

2. In simple myopic astigmatism, the rays going through one of the principal meridians, which is emmetropic, focus exactly on the retina, while those going through the other principal meridian fall short of the retina. See figure 24.

SIMPLE HYPERMETROPIC ASTIGMATISM.

Figure 23.

Vertical meridian is normal. Horizontal meridian is hypermetropic.

3. In compound hypermetropic astigmatism the rays are too long and are projected beyond the retina through both the principal meridians, the point of focus however in one direction being behind that of the other. See figure 25.

SIMPLE MYOPIC ASTIGMATISM.

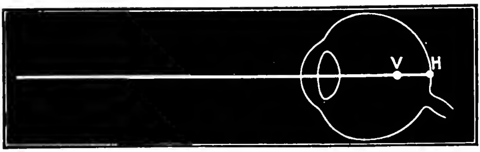


Figure 24.

Horizontal meridian is normal. Vertical meridian is myopic.

4. In compound myopic astigmatism, the rays passing through both principal meridians fall short and are focused before they reach the retina; those in one direction com-

ing to a focus more quickly than those situated at right or opposite angle. See figure 26.

5. Mixed astigmatism, as the term suggests, is a mixture of the conditions found in the first and the second

COMPOUND HYPERMETROPIC ASTIGMATISM.

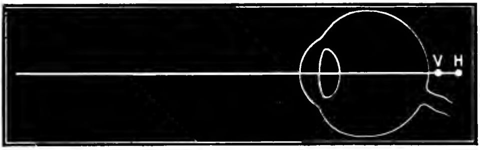


Figure 25.

Both meridians are hypermetropic. The horizontal is more so than the vertical.

varieties. The person is hypermetropic in one direction and myopic in the other. The rays coming through one principal meridian are brought to a focus before they reach the retina, and the rays coming in at the opposite meridian

COMPOUND MYOPIC ASTIGMATISM.

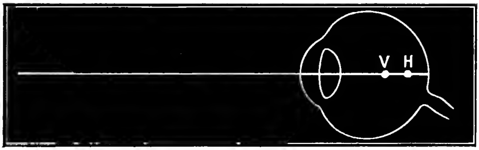


Figure 26.

Both meridians are myopic. The vertical more so than the horizontal.

are brought to a focus beyond the retina. See figure 27.

6. Irregular astigmatism is the condition in which there are several refractive errors in the same meridian. It may be either congenital or acquired. It is almost impossible

to correct these cases by lenses, although they may be improved to some extent, especially if a stenopeic slit set

MIXED ASTIGMATISM.

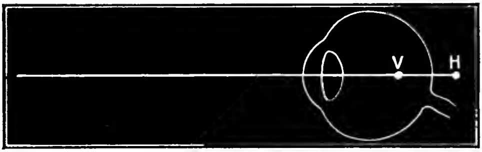


Figure 27.

Vertical meridian is myopic and the horizontal is hypermetropic.

at the best meridian (in order to cut off all other rays) is used, thus avoiding any metamorphopsia that may arise.

PRESBYOPIA OR OLD SIGHT.

Presbyopia, "old sight," is an accompaniment of the later years of life. It is a physiological or natural change, and affects all eyes. The condition is dependent almost solely upon the failure of the accommodation, this being due to a gradual hardening of the crystalline lens, rendering it incapable of increased convexity, and to a decrease of the power of the ciliary muscle.

Although this decrease in the power of adjustment for near objects is not evidenced until perhaps the fortieth or forty-fifth year of life, yet the change has been gradually taking place for years, and accommodation has been growing increasingly weaker. Fine print or near objects can no longer be seen distinctly at this period of life.

Presbyopia is assumed when there is difficulty in reading fine print within eight inches. The first symptom usually noticed is that it is difficult to distinguish fine type, and the work must be held further away from the eyes and more strongly illuminated in order to obtain distinct vision. These symptoms, which at first are pronounced by artificial light, will also later manifest themselves in the daytime.

In the treatment of this condition convex lenses are required to restore the near point. It is useless, by straining the eyes, to attempt to postpone the use of glasses. The popular opinion is to do so, but it is a great mistake. The longer the eyes are deprived of the aids of which they are in need, the more rapidly will the senile changes in the eye become developed. In old persons, when distant vision becomes indistinct, glasses of proper strengths should be worn constantly.

HYGIENE OF THE EYE.

Direction and source of light are of great importance, especially in doing near work. The ideal light, or that which is softest and most pleasant to the eye, is the diffused light from a northern sky. Next to diffused daylight, properly located incandescent electric lamps give the best light, because they burn steadier and radiate less heat than the burners which depend for their vitality upon the surrounding atmosphere. Gas and oil lamps consume more or less of the oxygen in the air, and there is always a tendency to rub the eyes after prolonged use, because they feel dry and hot, on account of the air becoming heated and vitiated.

An axiom in good artificial light is to keep the illumination of objects as strong as possible, but the intensity or brilliancy of lights as low as may be compatible for good vision. By all means shades should be employed over lamps in order to protect eyes from the direct rays of the light. It is well to intercept the rays. Opal, opaline, or ground-glass shades can be used for this purpose, though, unfortunately, they waste from thirty to sixty per cent. of the light. The *very best* method for effecting the better diffusion and distribution is accomplished by the use of "The Holophane Glass Globe" placed around the source of illumination. This is a system of compound prisms in which the very finest transparent glass is used. In consequence, the light is intensified and at the same time softened and diffused. By varying the angles of the prisms of which the globes are composed the light can be directed

over any desired point or space. Each facet is so arranged by carefully calculated measurements that the whole surface of the globe becomes softly luminous.

When artificial illumination must be resorted to, choice must be made for the best that can be procured, no matter what the source may be. It should be steady and direct, rather than that from a reflected or a flickering light. Light should enter from above and at the side, then to pass over the left shoulder, in order that it will strike the page of the book or the work. The aim should be to have the object which is desired to view thoroughly illuminated, and at the same time the eyes properly shaded. The importance of sufficient light is made quite manifest, if an attempt be made to read in a dimly lighted room, or in twilight. The work is brought nearer to the eyes in order to secure a larger retinal image and to obtain increased illumination. The consequent strain upon the accommodation and convergence brought about by this abnormal near point soon produces undue congestion of the eyeball and surrounding tissue, and thus leads to increased intra-ocular tension, with spasm of accommodation, resulting in headache and other nervous symptoms. Too much light, especially if it be reflected, is injurious, as it produces an overstimulation of the retina. Sudden changes from darkness to light, and *vice versa*, should be shunned. The eyes should not be dazzled by the light reflected from white paper, snow, water, or in fact, any polished surface.

There is no doubt that deficient and improperly admitted light in school rooms is one cause of the rapid progress of optical defects, especially myopia. In the first place, the desk should never be arranged so that the pupil faces the window. To sit facing a light during study is extremely injurious to the best of eyes. On looking up, the eye becomes saturated with light, and then on turning

to the printed page, an extra accommodative effort must be made to overcome the dazzle, and clear up the vision.

School furniture is often ill adapted for the scholar, even if it be properly placed in regard to light. The bench is often too high for the desk, so that the pupil must bend over his work, thus favoring congestion to the head and contributing to the congested condition at the back of the eyes. Often the seat is too far away from the desk, the head is thereby brought too near the book, so that the development of nearsight is directly encouraged.

It is of great importance that the desks and the seats should be of the proper height and angle. The desk should have a slight downward slope. The arrangement of the same must be such that the student will prefer the correct position rather than assume one that is abnormal although a more comfortable attitude. This, of course, also applies to "office" desks and illumination. This may seem trivial, but when it is considered that from five to six hours, or even longer, are spent each day in near work, it is advisable to give this subject considerable thought and attention. In making a selection of books, if possible, always choose those that have good unglazed paper, with large and clear type. Tinted paper is the most restful.

Reading should never be attempted while lying down, or when in a reclining posture. Many a tedious case of weak sight has been traced to the pernicious habit of reading in bed after retiring for the night. What is probably as bad, or worse, and a very common way of straining the eyes, is reading on railway trains. Here the constant oscillation of the car causes an over activity of the muscles, which soon become exhausted. Both the extrinsic and intrinsic muscles of the eye are forced into unnatural activity and tension. The result may easily be foretold; the eyes will sooner or later rebel and give out.

Individuals suffering or convalescing from a depressing illness or some disease of the eye, should employ the sight sparingly. It is not well to subject a delicate ciliary muscle to bear the continuous strain of accommodation, until the other muscles of the body have regained their full strength and firmness. One would not think of taking a long walk or doing any hard manual labor when just out of a sick chamber. How much more should the sensitive organs of vision be guarded !

When the eyes are painful and there is lacrymation, or when letters seem to run together, the work should be laid aside and the eyes directed to the distance. When possible, outdoor exercise and sleep should be taken. Work should only be resumed after a rest, and in case the symptoms recur work should be stopped.

Distant vision is a passive sensation and represents rest, and if the sight is normal, is not more exhausting than breathing, whereas near vision demands convergence and accommodation, and is, therefore, a muscular effort and requires exertion. Care should be taken not to unnecessarily increase the strain by holding the object too near the eyes.

All the organs of the body are better for moderate and judicious use, the eyes being no exception to the rule. Normally constructed healthy eyes should perform their work without the consciousness of the owner. The true test of this condition is that there shall be nothing to remind the user that he has eyes.

No specific rule can be laid down how long one should use his eyes, as even in health there is such a wide range of individual difference in vigor and endurance, and what may be safe or moderate work for one person would be a dangerous excess for another. The great peril of persons who have perfect and strong eyes, just as those who are

blessed with good health, *is overconfidence;* such individuals are very apt to be imprudent.

To preserve good sight, it is essential to maintain the whole economy in the highest state of health, and the first step in this direction is to have plenty of light and fresh air, combined with outdoor exercise Good, nutritious diet, with sufficient sleep, and proper division between labor and rest, should always be demanded.

Late hours, dissipation, fatigue, and overcrowded and ill-ventilated rooms should be avoided. Those who have a predisposition to catarrhal or rheumatic ailments should keep away from sudden changes of any kind, as such eyes frequently become the culminating point of disease. Violent affections or great passion, long-continued grief and care, cause a diminution of eyesight. These perpetually undermine both health and sight. Medical advice should be sought in regard to any disturbance that may be traceable to weak eyes. Headache and neuralgia often proceed from a latent defect of eyesight, or of the eye muscles, although such a sufferer apparently has perfect vision for both far and near. Suitable glasses will ofttimes give immediate relief.

Eyestrain may be said to exist whenever errors of refraction or mal-adjustment of the ocular muscles can be demonstrated. It is a frequent cause, and perhaps, the most important of all factors, that tend to produce functional nervous disease.

LIGHT.

Light is a form of ethereal vibration or undulations produced by a luminous body, and propagated in all directions with great velocity. A comparative example may assist in comprehending this theory more clearly: If a stone is thrown into a smooth sheet of water, a series of circular undulations, starting from the centre and gradually enlarging themselves, will be the result. So it is in the case of light. When a luminous body is placed in space the ether which surrounds it is thrown into a state of vibration, and the motion is immediately propagated in all directions. It is these undulations that excite the retina and produce the sensations of light. Light, like sound, is motion, while darkness, like silence, is rest. The natural and greatest source from which terrestrial light is derived is the sun, which body is in a constant state of incandescence.

All artificial sources depend upon the development of light during incandescence. Every form of matter, when sufficiently heated, has the power of emitting rays of light, and thus becoming incandescent and self-luminous.

Light obeys a simple but rigid law. It travels, when uninterrupted, in straight lines at the rate of 185,000 miles per second. Even at this tremendous velocity, it requires over eight minutes for a flash of light to reach the earth from the sun.

When rays of light emanate from an object situated at a distance of twenty feet (six metres) or more from the observer, they are considered as proceeding in parallel lines,

and they are supposed to enter the eye as such. Rays of light coming from an object which is nearer than twenty feet to the observer are regarded as proceeding from that point in lines which diverge, therefore fall upon the eye as divergent rays of light; the nearer the object the greater being the divergence.

REFRACTION OF LIGHT.

By refraction of light is understood the change of direction a ray or pencil of light undergoes when passing from

REFRACTION AND REFLECTION OF LIGHT.

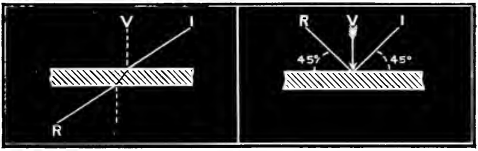


Figure 28.

REFRACTION.—(Left-hand figure). When a ray of light strikes a transparent object vertically, it passes directly through the same without being deviated in the least. The incident ray, I, meeting with a plate of glass is bent toward the vertical, and the refracted ray, R, passing from the glass is bent in the opposite, or from the vertical.

REFLECTION.—(Right-hand figure). Should a ray of light strike a mirror or polished surface, vertically (in the direction of arrow), the same would be reflected back on the same path. If, however, the same ray reaches the surface at an angle of 45 degrees, it will be reflected in the opposite direction, but precisely at the same angle.

one medium into another. Not all transparent media refract light equally; when a luminous ray passes from a rarer to a denser medium the light is bent or refracted toward the normal at the point of incidence; whilst if it passes from a denser to a rarer medium it will be refracted away from the normal at the point of incidence. In other words, when an incident ray strikes a smooth, transparent

surface vertically the beam passes straight through the same, or is unrefracted. Should the beam, however, strike the surface at an angle, the same will be refracted either toward or from the vertical, the deviation depending upon the course of the incident ray, as well as the refractive index of the substance. The greater the difference between the two the more the deflection. It is for this reason that a stick partly immersed in water appears to be broken or bent at the point of immersion. In the study of this branch of science the refraction of air and crown glass will alone be considered. If the index of the former is taken as the unit, or 100, the latter equals about 150 (or 50 per cent. more). See figure 28.

THE REFLECTION OF LIGHT.

The reflection of light is that property by which a ray of light rebounds or is sent out again when it strikes an object. The angle of reflection is always equal to the angle of incidence. It may be likened to the action of a billiard ball when it strikes a cushion—always glancing off at an equal angle to the original course. See figure 28.

SPECTACLE LENSES.

An ordinary lens or prism is composed of a piece of glass or other transparent substance, so formed as to change the direction of rays of light whilst passing through the same. Lenses are either convex or concave. The convex are designated as plus and the concave as

FORMS OR VARIETIES OF LENSES.

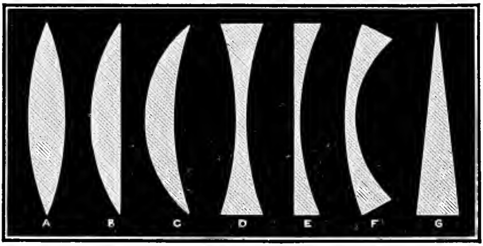


Figure 29.

A. Bi-convex or double convex. B. Plano-convex. C. Concavo-convex. D. Bi-concave or double concave. E. Plano-concave. F. Convexo-Concave. G. Plano-prism.

minus. The prefix sign + is used to designate the former and the prefix sign — the latter.

Rays of light, when passing through a lens or through a prism, have their direction altered; they are then said to have been refracted by the lens or by the prism. The deflection is always toward the thickest part of the lens.

There are two systems for numbering lenses; one is called the inch system and the other the dioptric system. The diopter is based on the metric scale, and is much the

better and the more preferable, as it is more scientific. At the present time it is used almost exclusively by physicians. Parallel rays from a distant object passing through a convex lens are brought to a point at F (see figure 30), and are said to be focussed.

CONVEX LENS.

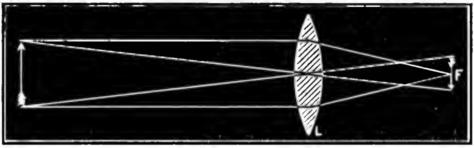


Figure 30.

Parallel rays are brought to a focus at F, on opposite side of lens.

This point is therefore called the principal focus of the lens L. The space intervening between the lens and its principal focus, F, will depend upon the degree of curva-

CONCAVE LENS.

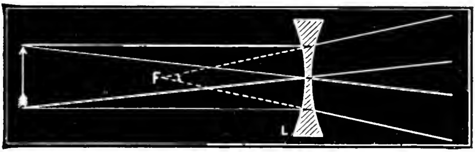


Figure 31.

Parallel rays are brought to a virtual focus at F, on same side of lens.

ture of the lens. If the distance between L and F is one metre, the lens has a focus of one metre, or as commonly called, it has the strength of one diopter. Such a lens is employed as a unit for calculation.

When luminous rays pass through a concave lens they

are refracted toward the thickest part of the lens, hence parallel rays from a distant object passing through such a lens will be refracted toward the periphery and pass as divergent rays. The focus, F, is situated on the same side of the lens on which the object lies; F would be at that point at which the diverging rays cross one another if they were continued backward. This is called the virtual focus. Hence the more divergent the rays are after their passage through a concave lens the nearer will F be to L (see figure 31). Consequently the more powerful the lens. A lens of weaker power would cause the rays to diverge to a lesser extent, and if continued backward they would

PLANO-PRISM.

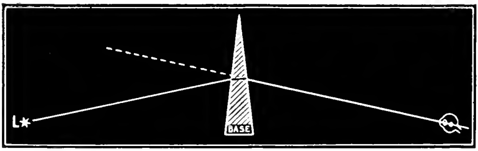


Figure 32.

Prismatic lenses displace objects in the direction of the apex, or edge. The light L, which is situated directly on a level with the eye, appears to come from the direction of the dotted line.

meet at a point situated more remote from the lens. Concave lenses are numbered and governed by the same law as convex ones.

Should the distance between L and F be only one-half metre, the lens would be double the strength of a 1. D lens, as it is evident that the lens that can bring parallel rays to a focus at a point of a half metre must necessarily have just twice the refracting power of one which focusses similar rays at a point one metre off.

A lens of	one diopter	(1. D)	will focus parallel rays at			1	metre,
"	two "	(2. D)	"	"	"	½	"
"	three "	(3. D)	"	"	"	⅓	"
"	four "	(4. D)	"	"	"	¼	" etc.

Therefore the higher the number of the lens in diopters the greater is its refracting power, and consequently the 2. D, 3. and 4. D. have respectively two, three and four times the strength of a one diopter lens. This law holds good in all forms of lenses.

PLANO CYLINDRICAL LENSES.

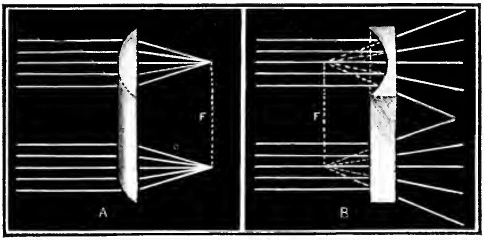


Figure 33.

A. Convex cylindrical lens. B. Concave cylindrical lens.

These lenses are used for the correction of astigmatism, and differ from spherical lenses because the rays refracted through them do not focus at a point, but focus as a line of light, as shown in figure. (Compare with figure 22.)

In the old, or inch system, a one-inch lens was used as the unit. Hence a No. 10 lens, or more properly speaking, a 1-10 inch lens, would focus parallel rays at 10 inches; a 1-24 inch lens at 24 inches, etc., but as the inch varied in different countries, there was always considerable confusion, and since the scientific world has adopted the metric system, the old way of measuring lenses has become obsolete.

OPTICAL GLASS.

Crown glass is selected for the superior brilliancy which it possesses, as the glass intended for optical use must necessarily be of exceptional transparency. Great care is exercised in selecting the raw materials employed in the manufacture of optical glass, so that they may be as pure as possible.

Glass is a transparent, hard, brittle substance formed by the fusion of silica (sand) and alkalies, a minute portion of white arsenic or peroxide of manganese being added on account of their bleaching properties.

Crown and plate glass are precisely of the same composition, and differ only in the manner in which the sheets of finished glass are produced.

The first step in the process of glassmaking is to fuse the ingredients in a pot or crucible. The metal being brought to a proper condition for manipulation, the operator dips an iron tube or blow-pipe, six or seven feet in length, heated at one end into a pot of metal. With this he takes up the glass, and by turning it gently around gathers about two pounds of molten glass on the end of it. Having allowed this to cool, he again dips the rod into the pot and gathers an additional quantity. This is also permitted to cool as before. The operation of dipping is repeated until a sufficient quantity, usually about ten pounds, is gathered. The rod, thus loaded, is held for a few seconds in a perpendicular position in order that the metal may distribute itself equally on all sides, and that it may be lengthened out beyond the rod by its own weight.

The workman then molds the metal into a regular form by rolling it out on a smooth iron plate. He then blows strongly through the tube, and thus causes the red-hot mass of glass to swell into a hollow pear or crown shape, hence its name. Then, by dexterously revolving the whole mass very rapidly, and constantly increasing the velocity until the portion adhering to the tube suddenly separates and flies open, the glass becomes a circular plane or sheet, four to five feet in diameter, of equal thickness throughout. The sheet, when fully expanded and cooled, is then tempered. To reduce its brittleness it is then annealed. It is subsequently polished and cut into blocks of various sizes. It is then ready for the grinder's lathe to be made into lenses.

SPECTACLE LENS GRINDING.

For this kind of work a special form of lathe somewhat similar to those employed by a lapidist is required. It consists of a trough made either of wood or of metal. It

LENS GRINDER'S LATHE.

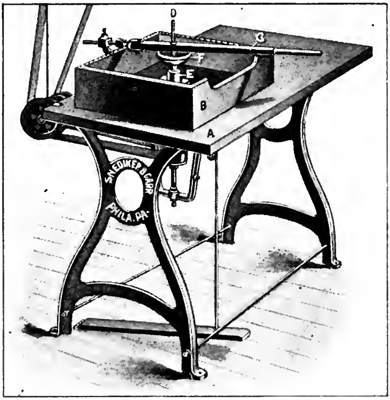


Figure 34.

A. Table or stand. B. Trough. C. Lever. D. Steel bar, the point of which holds lens in position on the grinding tool. E. Revolving spindle. F. Tool or mold on which the lens is ground.

is mounted on a stand or table. (See figure 34.) A vertical spindle-box passes through the bottom of the trough, and contains a shaft having upon its upper end a socket for the reception of the grinding tool. To the back of the

trough is attached a movable lever or handle with a universal joint, and on that part of the handle situated directly over the centre of the grinding tool there is a pointed steel bar which projects downward. This is intended to fit into the depression in the iron block, and

TOOLS FOR GRINDING SPHERICAL LENSES.

Figure 35.

A. Convex mold or ball for grinding concave spherical surfaces.
B. Concave mold or cup for grinding convex spherical surfaces.

holds the glass firmly in position on the grinding tool. At the same time it permits it to revolve freely.

In the grinding of spectacle lenses various stages are

TOOLS FOR GRINDING CYLINDRICAL LENSES.

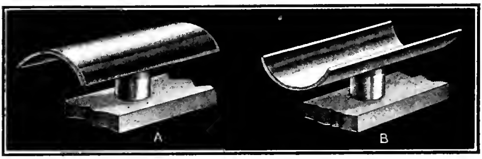


Figure 36.

A. Convex tool or mold for grinding concave cylindrical surfaces.
B. Concave tool or mold for grinding convex cylindrical surfaces.

necessary. The glass passes through the following procedure: A piece of optical glass is selected of the required thickness—about one and one half to two inches square. This is cemented, with a preparation of pitch and resin,

to a small iron block or holder, which has a slight depression (a shallow pit) for receiving the point of the steel prong on the lever. The next step is to select a mold of the desired curve.

For grinding spherical surfaces, molds similar to figure 35 are required, and the grinding is done by a rapidly revolving spindle. In grinding cylindrical surfaces the mold is fixed and the curve is attained by a steady to-and-fro motion. For these purposes tools similar to those seen in figure 36 are requisite. To grind a concave lens a convex mold, or ball, must be used.

To grind a convex one a concave mold or cup is selected. The strength of the lens depends upon the curvature, and not necessarily upon the thickness of the glass. The grinding is done by means of various grades of emery powder, starting with a coarse grain and finishing with the finest flour emery until the desired curve or focus has been acquired. For polishing the lens a piece of broadcloth is cemented to the surface of the grinding tool and coated with fine rouge moistened with water. The lens is held down with considerable pressure, and if the same has been well ground it quickly takes on a very highly polished surface.

It is almost needless to mention that both surfaces of the lens must undergo the same process, as only one side can be ground at a time.

The lens is now ready to be utilized for spectacles and eye-glasses, and can be cut into any desired shape or size. A thin, pliable metal pattern is laid upon the lens, and all superfluous glass is deftly cut away. The edges are then ground and smoothed, and the "lens is finished."

HISTORY OF SPECTACLES.

The word spectacles is derived from the Latin "*spectra*," and is defined as an optical instrument consisting of two lenses set in a frame, to be worn for the correction of ocular and muscular defects of the eye. These important aids to imperfect vision have been aptly termed "crutches for the eye." The origin of spectacles is involved in obscurity. In all the descriptions of the art of manufacture and the numerous uses of glass collected from ancient history there is not a word referring to the use of spectacles. It is probable that the ancients had some knowledge of optics, or at least that they understood the use of magnifying lenses in some form. The Chinese claim that they have used spectacles for the relief of defective eyesight for centuries. This may be so, but unfortunately, like all inventions made by them, they were, in consequence of their exclusiveness, useless to the rest of mankind. The only reference regarding lenses to be found is recorded in the Chinese Chronology of P. Gaubel, in which he tells us that the Emperor Chan, 2283 B. C., had recourse to an optical instrument to observe the planets.

Among the interesting relics brought to light in 1854 by the excavation of the ruins of ancient Nineveh, not the least remarkable was the discovery in the treasure house of a rock crystal lens which was found in company with bronzes and other articles of value. Its general shape was that of a plano-convex lens, the plane side having been formed of one of the original faces of the six-sided

crystal; the convex side had not been ground in a cup-shaped tool in the manner in which lenses are now formed, but had evidently been shaped on a lapidary's wheel, or by some such method. This is proof that the property of lenses was known to the ancients, and that they were employed by them long before the Christian era.

According to Seneca (4 B. C.), the ancients filled globes of glass with water and used the same as lenses; but no mention is made of their being used as spectacles.

One Roman historian reports that Nero (A. D. 68) had very defective vision, and at the gladiatorial games made use of a large jewel, the precious stone of which was shaped in the form of a lens, which enabled him to see to much better advantage.

Among the writings of Alhazan Abu Ali, who died A. D. 1038, at Cairo, Egypt, there was a work called "Thesaurus Opticæ." It is claimed that he introduced the knowledge of spectacles into Europe; but this is mere conjecture.

The year 1280 may be assumed as the one in which spectacles were invented, as no trace of any such invention can be found prior to that period. An old Latin document of the year 1303, found at the convent of St. Catherine of Pisa, records that Alexandro de Spina, who died in 1313, had a pair of spectacles made for himself by one who had the secret of their invention, but who refused to make known the true process of their manufacture. De Spina was so much pleased with the spectacles that he made the invention public. It was through his efforts that the employment of spectacles has become known.

"The Florentine Illustrated" states that Leopoldo del Migliore informs us that the first inventor of spectacles was Salvino Armato, who died in 1317. This is confirmed by the inscription on his tomb, which still exists at Florence.

Underneath his bust, carved on a large marble slab, may be read the following:

QUI GRACE
SALVINO D'ARMATO DEGLI ARMATI
DI FIRENZE
INVENTOR DEGLI OCCHIALI
DIO GLI PERDONIE A PECCATA
ANNO DMCCCXVII

(Here lies Salvino Armato d'Armati, of Florence, inventor of spectacles. May God pardon his sins. The year 1317.)

Another authority states that our first positive knowledge of spectacles is derived from the writings and experiments of Roger Bacon. He made many discoveries in optics and physics, and was the first to describe a convex lens. In describing spectacles, he stated that they were useful to old men and to those who have weak eyes, for it enables them to see the smallest letters sufficiently magnified.

Caessmaker has published some particulars of the early history of spectacles, which differ from those generally recorded. They are said to be the result of diligent researches among records of the convents and monasteries. According to this writer, Roger Bacon had spent some years at the convent of Cordeliers, at Lille, and during his stay formed a friendship with Henri Goethals, known better as Doctor Solemnel, and with Philip Mussche. To these men he paid annual visits during the vacations at Oxford, and availed himself of the opportunities of procuring from the Belgian glass manufactories fine glass fit for optical purposes. With this glass, polished by himself he made lenses, and communicated to his learned friends the secret of spectacles. In this manner it became known in Flanders and to the Dominican monks, to whom the

Italian writers attribute the invention. During the pontificate of Martin IV, who died in 1286, a question arose touching the interest of certain monks, who confided their defence to Henry Goethals. He being sixty years of age, used the spectacles, the lenses of which had been given to him by Roger Bacon. Arrived in Tuscany, Goethals visited Nicolas Messo, prior of the Dominicans, and stayed with them for some two or three weeks. It was in this way that Alexandro de Spina became acquainted with the use and the manufacture of spectacles. In the course of these researches it was also discovered that the sister of Goethals, abbess of the Hospital of the Hermitage, at Eeckergem, being dead, the religieuses preserved for a long time her glasses, which were mounted in gold.

In a manuscript written in 1299 by Pissazzo, the author says: "I find myself so pressed by age that I can neither read nor write without those glasses they call spectacles, lately invented, to the great advantage of old men when their sight grows weak."

Another ancient document relating to spectacles is dated in the year 1303. It is to be found in the Grand Chirurgie of Gui de Chaulic, which quotes the following, after having prescribed certain eye-salves: "If that does not suffice, recourse must be had to spectacles."

Mention is made of spectacles in a sermon preached in 1305 by a Florentine monk named Rivalto.

Friar Jordan, who died at Pisa in 1311, says in one of his sermons, which was published in 1305 (just when he preached the same is not mentioned), that "it is not much over twenty years since the art of making spectacles was discovered, and is, indeed, one of the best and most necessary inventions in the world."

It is also recorded that several cavaliers of the court of Guy de Dampierre, Count of Flanders, at the end of the

thirteenth century, wore spectacles, which in those days were always mounted in gold or silver frames, and were regarded as great treasures, receiving special mention in wills and deeds (see foot note), and were carefully preserved in cases of ebony and silver

An old chronicle of Nuremberg, Germany, of the year 1482, mentions that there were several manufacturers of spectacles in that city.

Savonarola, in 1490, during a discourse, informs us that as spectacles fell off, it was necessary to add small bars or hooks to the frames to fix them securely and prevent them from falling.

Whether the actual credit of the invention of spectacles is due to Alexandro de Spina, to Salvino Armato, or to Roger Bacon, is not of much consequence, especially as there seems to have been no distinct rule as to their application until about the year 1600. It was not known until that period why certain individuals required convex and others concave lenses. It was left for Kepler, who died in 1630, to demonstrate the manner in which rays of light are refracted through the humors of the eye and focussed upon the retina, thereupon forming a perfect image. He pointed out the real cause of myopia and hypermetropia, and taught how concave lenses rectified the former and convex lenses the latter.

The credit of making spectacles is also accorded to John Lippershey, a lens-grinder, of Middleburg, Holland, who, on October 2, 1608, petitioned the government for a patent on his claim for the invention of a telescope.

NOTE.—In the inventory of the valuables of the Emperor Charles V, made after his death, there are enumerated together collars and badges of the Golden Fleece, various charms, as the bezaor stone against the plague, gold rings from England, good for the cramp, a morsel of the True Cross, and twenty-seven pairs of spectacles.

It is related of Spinoza, who died in 1677, that he had learned the art of glass-grinding, so as to make a living while writing his philosophical works, and that he constructed a pair of spectacles for Liebnitz, who formed his acquaintance in Holland.

Benjamin Franklin has been credited with devising the first pair of double focus (or bi-focal) spectacles. In a letter dated May 23, 1785, he writes: "By Mr. Dolland's saying that my double spectacles can only serve particular eyes, I doubt he has not been rightly informed of their construction. I imagine it will be found pretty generally true that the same convexity of glass through which a man sees clearest and best at the distance proper for reading, is not the best for greater distances. I therefore had formerly two pairs of spectacles, which I shifted occasionally, as in traveling I sometimes read, and often wanted to regard the prospects. Finding this change troublesome, and not always sufficiently ready, I had the glasses cut and half of each kind associated in the same circle. By this means, as I wear my spectacles constantly, I have only to move my eyes up or down, as I want to see distinctly far or near, the proper glasses being always ready. This I find more particularly convenient since my being in France."

Thomas Young, who died in 1829, published an essay in 1794, in which he explained his own case of astigmatism.

David Brewster, who died in 1868, was among the first to correct astigmatism. He found that his own eyes had myopic astigmatism, and at his suggestion lenses to correct this defect were ground by Hill, of Edinburgh, and by Pritchard, of London.

George B. Airy fully appreciated the importance of correcting astigmatism in the year 1825, when describing

his own case he states that the vision of his left eye was so defective that he was unable to read or write, and the appearance of a candle flame was not circular as when seen with his right eye, but was shaped like an ellipse, with its long diameter at about 35 degrees.

It is recorded of Joseph Fraunhofer, who died in 1826, that he purchased a machine to grind spectacle lenses.

The researches of Donders, who died in 1889, created a new epoch in ophthalmology. His work, published in 1864, on Accommodation and Refraction of the Eye, is regarded as a masterpiece, and is the foundation of our present knowledge. He explained the various forms and anomalies of refraction, including astigmatism, and the method of their correction.

Until twenty five years ago very little attention was paid to the proper fitting of frames. Great importance is now not only attached but demanded for the correct fitting and centering of both frames and lenses.

Cemented bi-focal spectacles, *i. e.*, with a thin, supplemental lens cemented on the lower portion of the distance lens, as they are worn to-day, were first introduced in France. Just who ground the first pair in America is in doubt.

They came into general use about 1880–1885. When glasses are required for both distant and near vision, much can be said in favor of this form of spectacles, and they are worthy of recommendation. When the lenses are made properly and the frames are accurately fitted, they offer the best method of overcoming the loss of accommodation and the necessity of constantly changing glasses. They are a great convenience, and certainly save the wearer a great deal of trouble and annoyance. Patients soon learn to use them with great comfort, although occasionally a patient who cannot become accustomed to this

form of spectacles, will be met with. In the adjustment of bi-focal spectacles the habits, business, disposition, and personal peculiarities have all to be considered.

Spectacles were for a long time merely looked upon by some as mere objects of curiosity, and were made use of as a conspicuous novelty. In Spain they formed part of the costume of every well-bred person. This absurd use of glasses was meant to increase the gravity of the appearance, and consequently the veneration with which the wearer of them was supposed to be regarded.

The legitimate use of spectacles spread very slowly, because people had little need for them. Only a limited number of men could read or write. Books were scarce and costly, being only written by hand, as printing was not invented until the early part of the fifteenth century. The introduction and circulation of printed matter stimulated the demand for spectacles, and then their use rapidly increased.

At first the lenses were very large, and the frames were exceedingly heavy and clumsy. Until the beginning of the last century no improvements deserving notice either in the style or weight of the frames were made.

Spectacles of exquisite workmanship are now produced, the combined weight of frame and lenses not exceeding five to eight pennyweights. The photographs herewith will give an idea of development in the manufacture of spectacles. (See figure 37.)

Too much care and attention cannot be given to the preservation of sight, and it is not too much to say that through the aid of spectacles the enjoyment of one of the most valuable of our senses may be continued even in old age. Deprived of their help, most men at the age of fifty would be too old for work. In the evening of life they enable the mechanic to continue his labors, and the artist